Pointshop 3D

An Interactive System for Point-based Surface Editing

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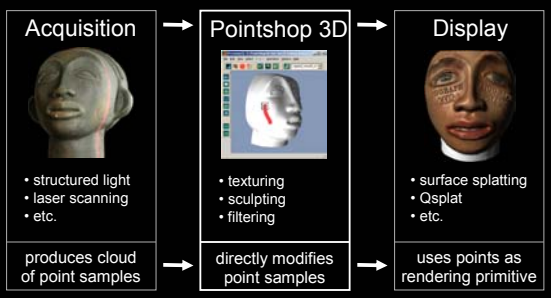
Outline

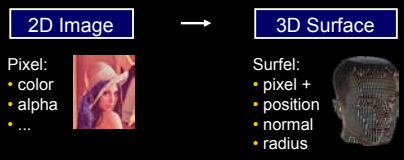
- Introduction
- Pointshop3D system components
  - Point cloud parameterization
  - Dynamic sampling
  - Editing operators
- Demo
- Conclusions

Point-Based 3D Content Creation



Pointshop 3D

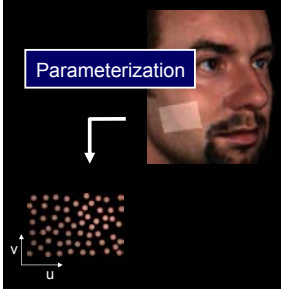
- Generalizes 2D photo editing concepts and functionality to 3D point-sampled surfaces



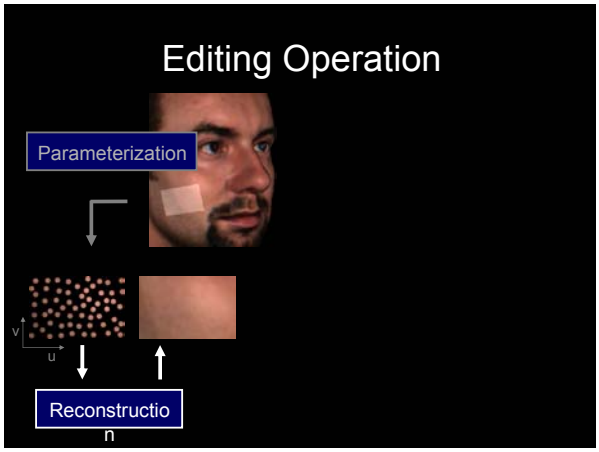
⇨ Geometry editing: modify 3D positions and normals, e.g. sculpting and filtering

Editing Operation

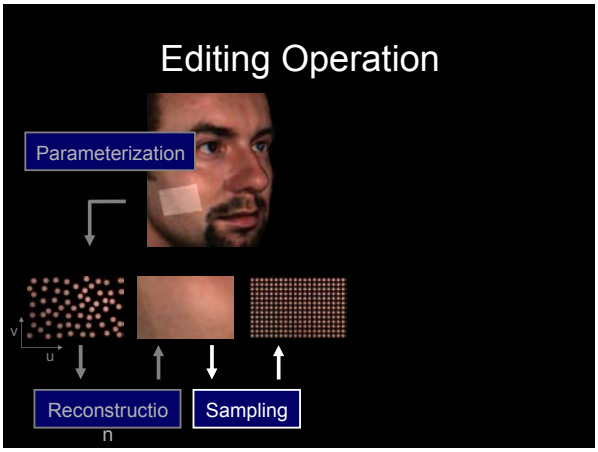
Editing Operation



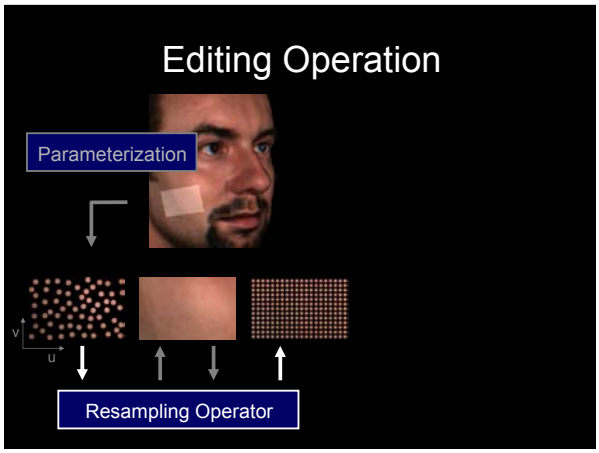
Editing Operation



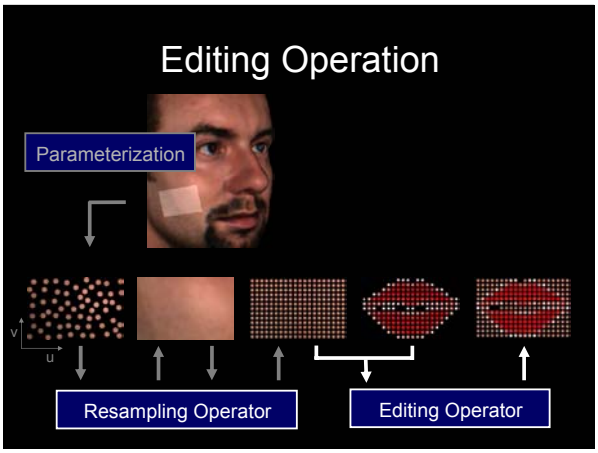
Editing Operation



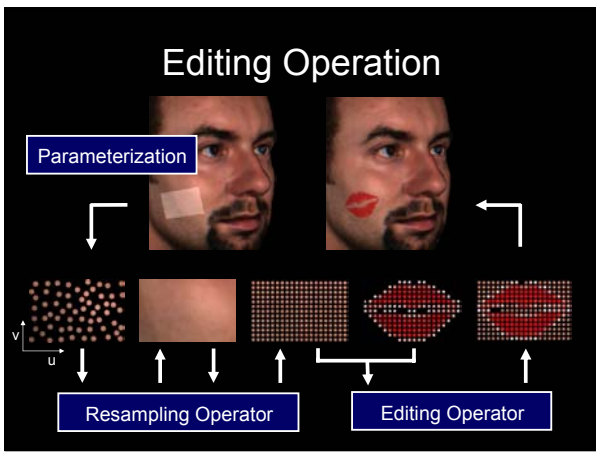
Editing Operation



Editing Operation



Editing Operation



Key Components

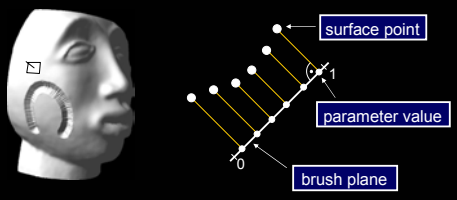
- Point cloud parameterization Φ
- Dynamic resampling Ψ
- Editing operator Ω

$$S' = \Omega(\Psi(\Phi(S)), \Psi(B))$$

modified surface | original surface | brush

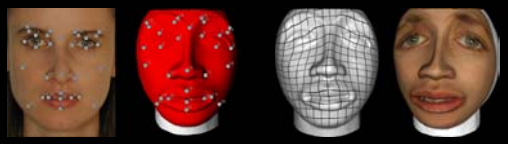
Point Cloud Parameterization

- Brush interaction
  - Parameterize by orthogonal projection



Point Cloud Parameterization

- Selection interaction
  - Constrained minimum distortion parameterization



Constraints | Minimum Distortion

Point Cloud Parameterization

- Minimize objective function

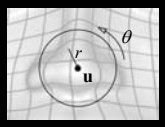
brush points | surface points

$$C(X) = \underbrace{\sum_{j \in M} (X(\mathbf{p}_j) - \mathbf{x}_j)^2}_{\text{fitting constraints}} + \underbrace{\varepsilon \int_P \gamma(\mathbf{u}) d\mathbf{u}}_{\text{distortion}}$$

Point Cloud Parameterization

- Measuring distortion

$$\gamma(\mathbf{u}) = \int_\theta \left(\frac{\partial^2}{\partial r^2} X_{\mathbf{u}}(\theta, r) \right)^2 d\theta$$



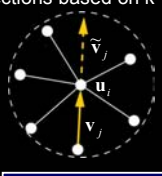
- Integrates squared curvature using local polar re-parameterization

$$X_{\mathbf{u}}(\theta, r) = X\left(\mathbf{u} + r \begin{bmatrix} \cos(\theta) \\ \sin(\theta) \end{bmatrix} \right)$$

Point Cloud Parameterization

- Discrete formulation:
  - Approximate second derivative with divided differences
  - Discretize integral using normal sections based on k-nearest neighbors

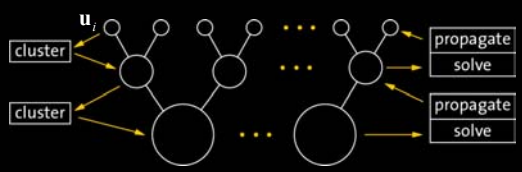
$$\gamma(\mathbf{u}_i) \approx \sum_{j \in N_i} \underbrace{\left(\frac{\partial X(\mathbf{u}_i)}{\partial \mathbf{v}_j} - \frac{\partial X(\mathbf{u}_i)}{\partial \tilde{\mathbf{v}}_j} \right)^2}_{\text{discrete curvature}}$$



k-neighborhood

Point Cloud Parameterization

- Discrete formulation:
  - Leads to a linear least squares system
  - Efficiently solved using multi-grid approach



Reconstruction

- Parameterized scattered data approximation

fitting functions

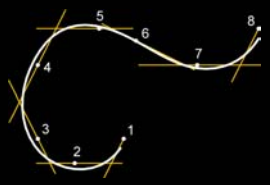
weight functions

$$S(\mathbf{u}) = \frac{\sum_i \Phi_i(\mathbf{u}) r_i(\mathbf{u})}{\sum_i r_i(\mathbf{u})}$$

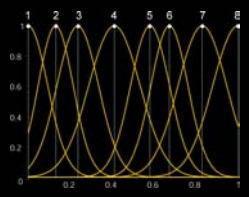
normalization factor

- Compute local fitting functions using local parameterization
- Map to global parameterization using global parameter coordinates of neighboring points

Reconstruction



reconstruction with linear fitting functions



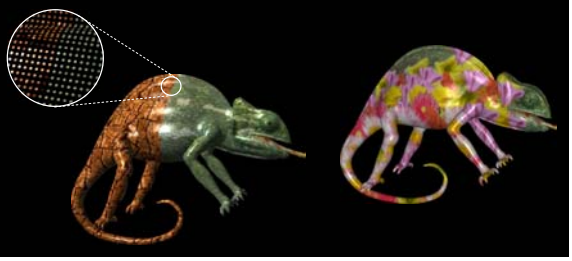
Gaussian weight functions in parameter space

Sampling

- Three sampling strategies:
  - Sample at the original surface points
  - Sample at the brush points
  - Adaptive sampling, i.e. sample at surface or brush points depending on the local sampling density
- Antialiasing
  - Band-limit the weight functions (Gaussians) before sampling using Gaussian low-pass filter
    - ⇨ Surface splatting framework

Editing Operators

- Painting
  - Texture, material properties, transparency



Editing Operators

- 3D Sculpting

brush | normal displacement | carving on a rough surface | brush

Editing Operators

- Filtering

geometry smoothing filter | artistic texture filter

Demo

Discussion

- Efficient point-based surface resampling
- Robust reconstruction based on k-nearest neighbors requires:
  - No outliers
  - Sufficiently high, roughly uniform sampling density
  - Little noise
- Geometry editing is restricted to displacements

Ongoing & Future Work

- Model cleaning
  - User-guided ⇨ provide appropriate tools
  - Automatic pre-process
- More general modeling functionality
  - Free-form deformation
  - Physics-based modeling
- Texture synthesis and transfer

Conclusion

- Pointshop3D provides sophisticated editing operations on point-sampled surfaces
  - ⇨ points are a versatile and powerful graphics primitive
- Software release in fall 2002 on

www.pointshop3d.com

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- Tim Weyrich
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